Intensity Frontier Fellowship Closeout Report

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The new muon g-2 Intensity Frontier experiment at Fermilab requires the precise measurement of two quantities: the muon's anomalous spin precession frequency ω_a in a magnetic storage ring, and the magnetic field strength expressed in terms of the equivalent Larmor precession frequency of a free proton ω_p. An Intensity Frontier Fellowship from September 1st 2015 through August 31st, 2016 supported my activities directed towards shimming the g-2 storage ring magnetic field, and the development of instrumentation for the measurement of ω_p. Fellowship support was vital for the success of these efforts.

Magnet Shimming: In September 2015 I started work on shimming the magnetic field of the storage ring. This was a 9 month long process of making fine mechanical adjustments to the 680 tons of iron that compose the magnet to make the field as uniform as possible. This was a large effort involving collaborators from Fermilab, University of Washington, University of Massachusetts, Argonne National Lab, and University of Michigan. The process was a laborious cycle of magnetic field measurement, analysis, and repositioning of 72 magnet pole pieces with a precision of ± 0.0005". This was followed by shimming using a new technique developed by our group. This involved the placement of more than 8,000 thin iron foils of custom widths determined by an optimization algorithm that further reduced the field inhomogeneities around the storage ring significantly. The resulting field quality met the technical goals for the new experiment, and surpassed that achieved by the Brookhaven g-2 experiment by about a factor of 4. A plot of the initial and near-final magnetic field strength as a function of azimuth is shown in Fig. 1.

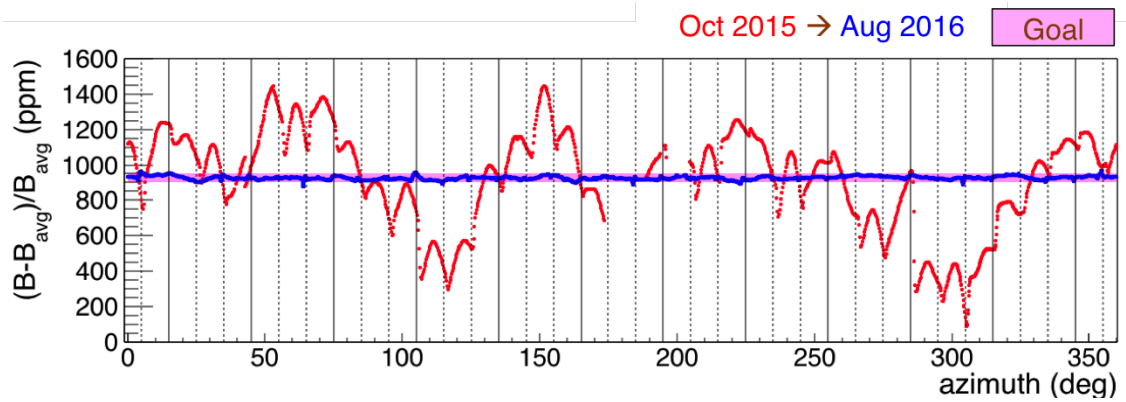

Figure 1: The plot shows the variation in magnetic field strength around the circumference of the storage ring in October 2015 before shimming (red line), and August 2016 after shimming (blue line). The stretch goal of ± 30 ppm variation around the ring was achieved after significant effort by the shimming team.

Magnetic Field Measurement: A second set of activities involved setting up a magnetic field measurement facility at nearby Argonne National Laboratory. We used an MRI magnet at 1.45 T to develop and test new high precision pulsed NMR electronics and probes, and demonstrated single shot field resolution below 100 parts-per-trillion. The system, developed with IFF support, will be transported to Fermilab to measure the storage ring magnetic field strength in terms of the equivalent free proton precession frequency with a target accuracy of 35 ppb.

Other Activities: The IFF supported work on measuring time-dependent external magnetic fields (from the Booster, 60 Hz, and other higher frequency fields) in the muon g-2 experimental hall and muon storage volume, and investigation of a feedback system to mitigate these fields using a coil near the muon storage volume. Progress was made on the field perturbation measurements, but the feedback effort was unsuccessful. Further work will be necessary.